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Research Article

Abundance, diet and food availability of Citreoline Trogon (*Trogon citreolus*) in a regenerating tropical dry forest in the Central Pacific, Mexico

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Abstract

Trogonidae make up a family of birds with a mixed diet composed of fruit and animal matter. However, there is little research examining the foraging ecology of *Trogon citreolus* in regenerating tropical forest. We studied *T. citreolus* abundance and diet from November 2020 to April 2022 in a regenerating dry tropical forest of Central Pacific Mexico. Also, we investigate the relationship between food availability and trogon abundance. The relative trogon abundance was 2.6 ± 2.3 individuals per point count, which varied temporally. The species consumed the fruits of 14 plant species from 10 families. The three most consumed species were *Ficus cotinifolia*, *Comocladia engleriana*, and *Randia gentlei*. *Trogon citreolus* displayed a moderate niche breadth (B_{est} = 0. 420) whit low food diet diversity (H' = 0.94), and the dominance of a particular type of food (λ = 0.85). Our results demonstrated a positive correlation between trogon abundance and food resource availability. The dietary breadth of *T. citreolus* enable the species to adapt to fluctuations in fruit availability in regenerating forests. These findings highlight the ecological importance of forest regeneration in providing food resources for *T. citreolus* and other frugivorous birds.

Key words: Frugivorous birds, fruit availability, Levins index, phenology transects, successional dry forest, Trogonidae

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Introduction

In the context of regenerating forests, an understanding of how birds utilize food resources and their responses to changes in food availability is of significant value for the effective management of habitats and the conservation of species (Fleming 1992). In tropical birds, there is evidence that food availability is related to temporal changes in abundance, and also influences foraging behavior (Levey 1988; Loiselle 1988). Trogons and quetzals (Trogonidae) inhabit the tropical regions of America, Asia, and Africa. The Trogonidae family comprises 46 species, 25 of which are found in the Neotropical region, including nine species distributed in Mexico (Winkler et al. 2020). These birds have a

mixed diet composed of fruits from diverse tropical plants and animal items such as caterpillars, insects, and small vertebrates (Remsen et al. 1993; Avila et al. 1996; del Hoyo et al. 2001; Pizo 2007; Riehl and Adelson 2008). The influence of fruit availability on population density and altitudinal migration patterns in this avian group has been documented, as demonstrated by the quetzal (*Pharomachrus mocinno*) within its breeding range in Costa Rica and southeastern Mexico (Wheelwright 1983; Solórzano et al. 2000).

Among trogon species, the Citreoline Trogon (*Trogon citreolus* Gould, 1835), an endemic species of Mexico, is found along the Pacific slope from Sinaloa to northwestern Chiapas, mainly associated with tropical dry and semi-deciduous forest, mangroves and secondary growth forests (Howell and Webb 1995; Collar 2020). The Citreoline Trogon has been observed to consume both fruits and small invertebrates as part of its diet (Skutch 1948). Eguiarte and Martínez del Rio (1985) observed that the Citreoline Trogon exhibited a frugivorous diet during the dry season in preserved forests in Mexico. Other studies indicate that the species exhibits plasticity in the use of food resources throughout the year, including the consumption of fruits from February to June, insects from July to October, and a combination of fruits and insects from November to January (Morán-Dimayuga 2002; Collar 2020). Nevertheless, there has been a paucity of research examining the foraging ecology of *T. citreolus* in regenerating forest ecosystems. Identifying the tree species that comprise the Citreoline Trogon's diet in these habitats is crucial for developing effective long-term habitat-management strategies.

The Citreoline Trogon is not legally protected by Mexican laws (SEMARNAT 2010) and there is no published information regarding their abundance (Collar 2020). In this paper, we aimed to determine the relative abundance and diet of *T. citreolus*, the relationships between food sources availability and trogon abundance in a regenerating dry tropical forest of Central Pacific, Mexico. We tested the hypothesis that food resource availability affects the abundance and foraging behavior of *T. citreolus*. Additionally, we predicted that changes in *T. citreolus* abundance are related to local fruiting patterns, with some plant species having the highest frequency of consumption.

Materials and methods

Study area

The study was conducted at the Puerto Escondido Botanical Garden of the Universidad del Mar (hereafter JBPE), in the coastal plain of Oaxaca, southwestern Mexico (15°54'41.7"N, 97°04'29.2"W; 15°55'1.0"N, 97°04'52.9"W; Fig. 1). The JBPE consists of 16.7 hectares intended for the study and conservation of regional biodiversity (Fig. 1A). The site was previously used for planting corn, beans, sesame, and pumpkin between 1972 and 1983. In 2004, the municipal government donated the area to the Universidad del Mar (Luis-Reyna 2018). The site is distinguished by the presence of a rugged topography, with hills that range in elevation from 70 to 160 masl and small ravines that traverse the site.The area is currently dominated by tropical dry forest (Rzedowski 2006) that has undergone 20 years of secondary succession, allowing for vegetation repopulation (Fig. 1B). The most common plant families include Anacardiaceae, Annonaceae, Burceraceae, Fabaceae, and Rubiaceae. Common tree species in the area are

Bursera simaruba, *Ceiba parvifolia*, *Cochlospermun vitifolium*, *Comocladia engleriana*, *Guapira macrocarpa*, and *Tabebuia chrysantha* (Luis-Reyna 2018). The region is characterized by a warm, subhumid climate with summer rains. There are two distinct seasons, the dry season from November to May and the wet season from June to October. The average annual temperature ranges from 22 to 43.2 °C, and precipitation ranges between 800 to 1000 mm (Trejo 2004).

Abundance and diet of *Trogon citreolus*

From November 2020 to April 2021, we counted individuals of *T. citreolus* using the point counts method with a fixed radius of 30 m (Bibby et al. 1992; Gildardi and Munn 1998). We established 15-point counts, which were geo-referenced using GPS, to maintain a distance of 150 m between points and ensure the independence of the records (Fig. 1). At each point, we conducted a 10 min count to record all individuals of *T. citreolus* seen and heard. The sound records were considered for a single individual, regardless of group size. For each record, we noted the date, time, number of individuals, activity (hatch, flight), and foraging observations. Counts were conducted by a single person (EFD) in the morning from 6:00 to 10:00 h and in the evening from 16:30 to 18:30 h.

We determined diet through focal observations of foraging trogon during the same period and time as the point counts. We also considered opportunistic observations of foraging trogon when these were encountered outside the point counts. For each forage record, we noted: (1) date and time; (2) number of individuals; and (3) tree species. We considered a foraging record as one or more individuals feeding on a tree; when the individuals moved to another resource of the same tree or another tree, this was considered a second foraging record (Galetti 1993). Foraging records were carried out by a single person using binoculars (MADLH).

Food resource availability

We established 10 phenological transects (100 × 4 m) (Fig. 1) to determine food resource availability for trogons (Chapman et al. 1992). Phenological transects were visited monthly from November 2020 to April 2021. In transects, all fruit trees or shrubs were marked and identified. For each fruiting tree or shrub, we measured the diameter at breast height (DBH) and estimated the proportion of fruits in the crown based on four categories (1 = 0–25%; 2 = 26–50%; 3 = 51–75% and 4 > 75%) (Chapman et al. 1994). We calculated a fruit abundance index by multiplying tree DBH by the proportion of the canopy with fruits (∑ (DBH * proportion of fruits)/number of transects) (Chapman et al. 1992). Additionally, for each transect, we considered the number of tree species fruiting, the number of fruiting trees/shrubs, and the sum of the fruit abundance index, as variables of food resource abundance that could be compared among months. Tree and shrub species were identified in the field or by means of botanical sampling collected for later identification at the Laboratory of Biological Collections of the Universidad del Mar, campus Puerto Escondido. Tree identification and nomenclature followed Salas-Morales et al. (2003), Pennington and Sarukhán (1998), Salas-Morales et al. (2007), García-Mendoza and Meave (2011), and Pérez and Barajas-Morales (2011).

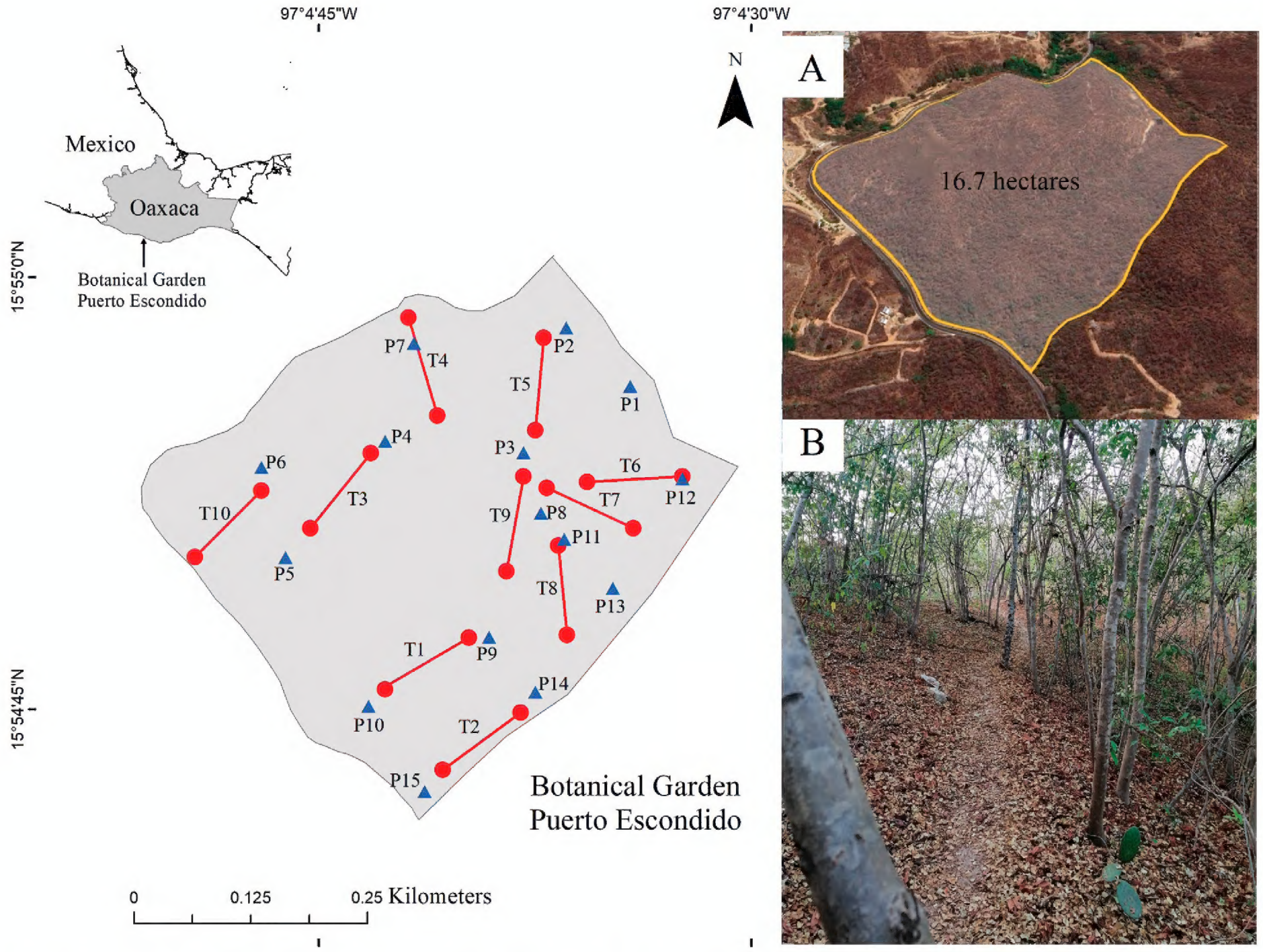

Figure 1. Location of the Puerto Escondido Botanical Garden of the Universidad del Mar, coastal plain of Oaxaca, southwestern Mexico. The point counts are indicated with "P" and the phenological transects with "T". (A) the area covered by the Botanical Garden. (B) example of the plant structure.

Statistical analysis

The relative abundance of *T. citreolus* was calculated monthly (November 2020 to April 2021) by dividing the number of individuals recorded per point count by the total point counts. Due to the data not meeting the assumption of normality (Shapiro-Wilk) even with logarithmic transformation, we compared the relative abundance of *T. citreolus* using the Friedman nonparametric test and Tukey-Kramer post hoc test with Bonferroni adjustments, to identify the pattern of change in abundance over the study period (Quinn and Keough 2002). Foraging records were used to estimate the food-niche breadth of *T. citreolus* using the Levins standardized index (B_{est} = (B - 1) / (n - 1); where B = 1 / Σp_i^2 y p_i = proportion of individuals using the resource i (Levins 1968; Hulbert 1978). This index expresses the niche breadth on a scale from 0 (narrow niche), indicating that the use is concentrated on a few resources, to 1 (wide niche), when the resources are equally used (Colwell and Futuyma 1971). The niche breadth quantifies the species' specialization within a given environment (Krebs 1999). To describe diet diversity, we calculated Shannon-Wiener's index, $H' = \Sigma\ p_i \ln pi$, and Simpson index, $\lambda = 1\text{-}\Sigma(p_i)^2$ (Sherry 1990). In regard to the Shannon-Wiener index, the following arbitrary criteria were employed: (a) if the value $H' > 3$, it is defined as high food diversity; (b) if the H' value is within the 1–3 interval, it is

defined as moderate food diversity; and (c) if the value of $H' < 1$, it is defined as low food diversity. The criteria for the Simpson index value are: (a) if the λ value is close to 0, no particular food type dominates, and (b) if the λ value is close to 1, there is a particular food type that dominates.

Additionally, we compared the fruit availability recorded in the 10 phenological transects in terms of the number of species fruiting, the number of fruiting trees, and the sum of a fruit abundance index, to evaluate whether there was variation in resource availability. We performed either parametric tests (repeated-measures ANOVA) or non-parametric tests (Friedman), according to the normality of the data (Shapiro-Wilk), and when significant differences occurred, we applied the post hoc Tukey-Kramer test to determine which group produced a significant difference among months (Quinn and Keough 2002). Ultimately, Pearson's correlation test was employed to ascertain the relationship between *T. citreolus* abundance and fruit availability for all trees, as well as fruit availability for diet trees (Zar 1999). The analyses considered the fruit abundance index and the number of individuals recorded per point count for each month. To ensure consistency in the analysis, the trogon abundance recorded at points 1–2, 4–5, 8–11, 9–10, and 14–15, which were near phenology transects (Fig. 1), was averaged. This adjustment allowed for an identical number of phenology transects and point counts (n = 10). Analyses were carried out using R statistical software with the package "*rstatix*" (R Core Team 2016). Descriptive statistics are presented as mean with standard deviation, and we considered $P < 0.05$ as significance differences in statistical analyses.

Results

Trogon citreolus abundance

During the study period, we obtained a total of 159 records of *T. citreolus*. The largest number of records occurred in April (*n* = 46; 28.9%), followed by March (*n* = 29; 18.2%), and the smallest number occurred in December (*n* = 16; 10.1%). The relative abundance of *T. citreolus* was 2.6 ± 2.3 individuals per point count. *T. citreolus* exhibited a steady pattern of abundance (November 2021–March 2022), with an increase at the end of the study period in April 2022. The Friedman test indicated that significant differences in trogon abundance occurred between months (Friedman $X^2_5 = 11.32$, $P = 0.045$; Fig. 2). The Tukey post hoc test showed that trogon abundance was significantly higher in April (3.9 ± 2.5 individuals; n = 59; interval: 0–9), compared to December ($Q = 4.07$, $P < 0.05$), the month with the lowest abundance (1.1 ± 1.0 individuals; n = 17; interval: 0–3). No other comparisons were significant ($P > 0.05$).

Trogon diet and food niche breadth

We obtained a total of 41 foraging records of *T. citreolus* (n = 88 individuals), consuming 14 plant species from 10 families (Table 1). Only fruit consumption was recorded during the foraging observations, and no other items were consumed. The most common plant families in the trogon diet were Anacardiacae (34.1%; n = 19 individuals), Rubiaceae (17.1%; n = 21 individuals), Moraceae (12.3%; n = 24 individuals), and Vitacae (9.8%; n = 6 individuals) (Table 1).

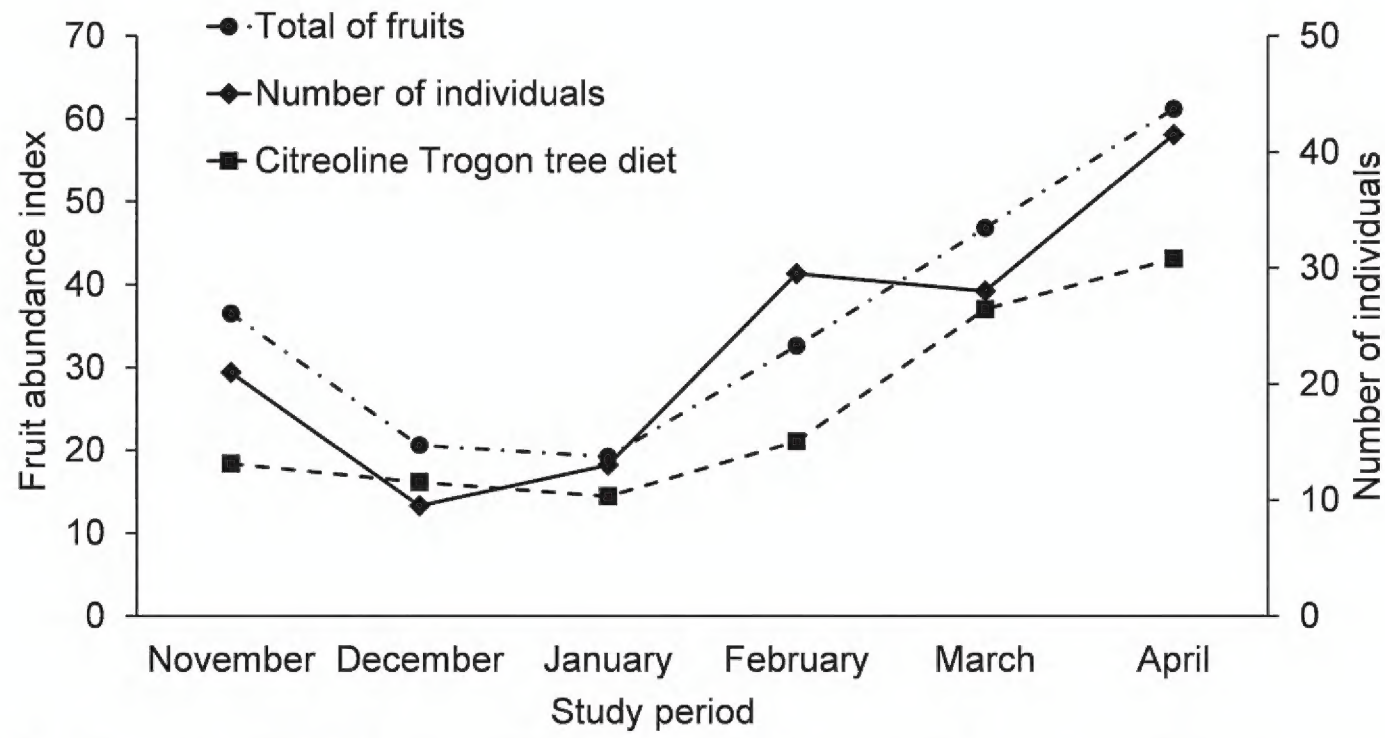

Figure 2. Relationship between fruit abundance index and abundance of *Trogon citreolus* in the tropical regenerating dry forest of the Puerto Escondido Botanical Garden from November 2020 to April 2021.

Table 1. Diet of *Trogon citreolus* in the regenerating dry tropical forest of the Puerto Escondido Botanical Garden, coastal plain of Oaxaca, southwestern Mexico, from November 2021 to April 2022. The percentage (%) is shown in parentheses.

Family	Specie	Common name	Foraging records	Number of individuals	Month
Anacardiaceae	*Comocladia engleriana* Loes.	Tetlatia	12 (29.3)	17 (19.3)	February–March 2021
	Spondias purpurea L.	Mexican plum	2 (4.9)	2 (2.3)	April 2021
Apocynaceae	*Tabernaemontana grandiflora* Jacq.	Wedding tree	1 (2.4)	1 (1.1)	December 2020
Burseraceae	*Bursera simaruba* (L.) Sarg.	Gumbo limbo	1 (2.4	1 (1.1)	January 2021
Ebenaceae	*Diospyros verae-crucis* (Standl.) Standl.	Willow Leaf Persimmon	3 (7.3)	4 (4.5)	November 2020, January 2021
Moraceae	*Ficus cotinifolia* Kunth	Poplar tree	5 (12.2)	24 (27.3)	January 2021
Passifloraceae	*Passiflora* sp.	Passionfruit	3 (7.3)	6 (6.8)	December 2020, January 2021
Polygonaceae	*Coccoloba barbadensis* Jacq.	Fresh watergrape	1 (2.4)	2 (2.3)	February 2021
	Coccoloba liebmannii Lindau	Liebmann´s seagrape	1 (2.4)	3 (3.4)	February 2021
Resedaceae	*Forchhammeria pallida* Liebm.	Olive tree	1 (2.4)	1 (1.1)	January 2021
Rubiaceae	*Hamelia longipes* Standl	Long-stemmed Firebush	1 (2.4)	2 (2.3)	February 2021
	Hintonia latiflora (Sesse & Moc. Ex. DC.) Bullock	Bitter tree	3 (7.3)	5 (5.7)	January 2021
	Randia gentlei Lundell	Wild calabas	3 (7.3)	14 (15.9)	December 2020, January 2021
Vitaceae	*Ampelocissus acapulcensis* (Kunth) Planch	Grape vine	4 (9.8)	6 (6.8)	March – April 2021

Among the plant species listed in Table 1, 57.2% correspond to mature deciduous tropical forest species, while 42.8% are common in regenerating forests (Pennington and Sarukhán 1998; Rzedowski 2006).

Considering the number of trogons using each food resource, we calculated an overall Levins´ niche breadth of B_{est} = 0.420. This represents a moderate niche breadth where use was spread relatively equally over the resources, with six plant species contributing > 5% of the diet. Nevertheless, three plant species

contributed more than 60% of the trogon diets, with more individuals recorded consuming fruits of *Ficus cotinifolia* (n = 24 individuals; 27.3%), *Comocladia engleriana* (n = 17 individuals; 19.3%), and *Randia gentlei* (n = 14 individuals; 15.9%) (Table 1). The Shannon-Wiener Index showed low food diet diversity (*H'* = 0.94), and the Simpson Index showed the dominance of a particular type of food (λ = 0.85), *F. cotinifolia* exhibited the highest frequency of consumption by *T. citreolus*.

Temporal variation in food resource availability

We recorded 266 trees of 28 species from 13 families in the phenology transects (See Suppl. material 1). Plant families with the largest number of tree species fruiting were Fabaceae (n = 23 species), Rubiaceae (n = 9 species), Polygonaceae (n = 5 species), Apocynaceae (n = 4 species), and Bignonaceae (n = 4 species). Figure 3 illustrates the phenological patterns of the diet trees (n = 9) of the *T. citreolus* documented at the study area. The most abundant diet trees fruiting in November and December 2021 were *Randia gentlei*, *Diospyros verae-crucis*, and *Tabernaemontana grandiflora*, in January and February 2022 were *D. verae-crucis*, and *Coccoloba liebmannii* and in March and April 2022 were *D. verae-crucis*, and *Spondias purpurea. Hintonia latiflora* and *Coccoloba barbadensis* only fruited during November and April, respectively. On the other hand, four species that are part of *T. citreolus* diet were not recorded in the phenology transects (Table 1). However, we observed the presence of fruits on *Ficus cotinifolia* and *Forchhammeria pallida* in January, *Passiflora* sp. in December-January, and *Ampelocissus acapulcensis* in March.

Considering all fruiting trees, there were significant differences in food resource availability during the sampling period. This was evidenced in the number of tree species fruiting ($F_{5,59}$ = 17.8, P < 0.001), the number of trees fruiting ($F_{5,59}$ = 3.4, P = 0.011), and fruit abundance index (Friedman X^2_5 = 38.7, P < 0.001) (Table 2). Post hoc test (Tukey-Kramer) found significantly more tree species fruiting and a larger number of trees fruiting in November and April. In terms of fruit abundance index, there was a significant increase during March to April (Table 2).

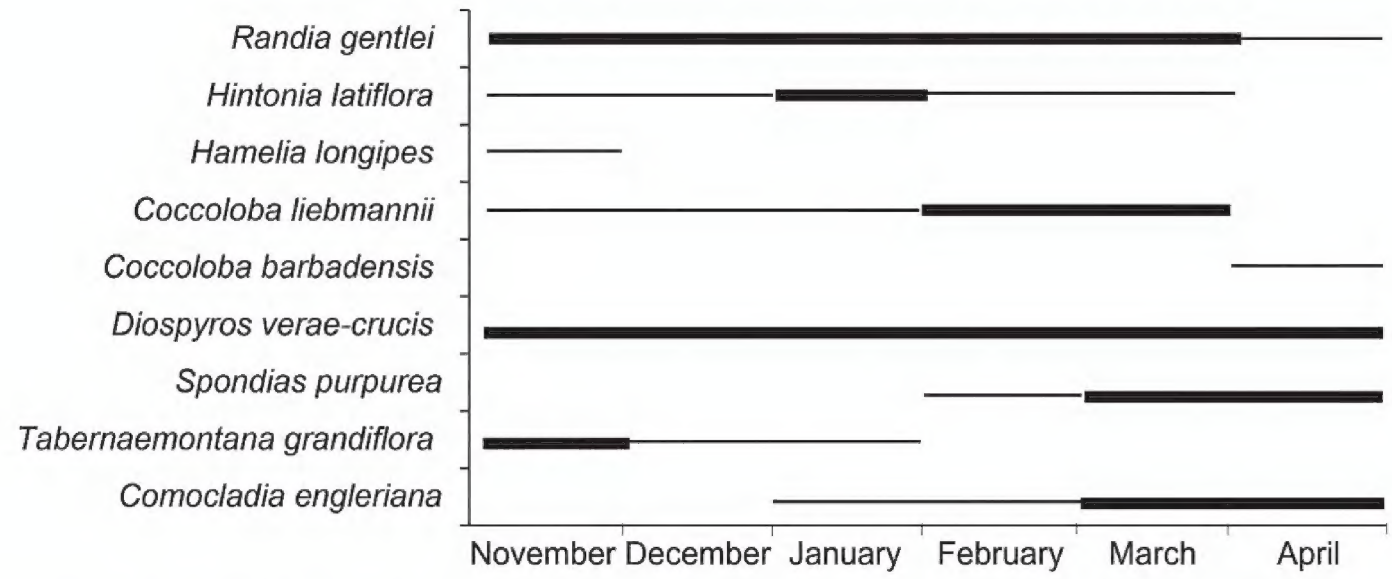

Figure 3. Fruiting phenology of nine tree and shrub species consumed by *Trogon citreolus* at Puerto Escondido Botanical Garden, Oaxaca, Mexico, from November 2020 to April 2021. Thick lines indicate high density of fruiting individuals (>5 individuals/0.4 ha), and thin lines indicate low density of fruiting individuals.

Table 2. Mean (± SD) food resource availability for *Trogon citreolus* from November 2020 to April 2021 at Puerto Escondido Botanical Garden, Oaxaca, Mexico, with parametric (one-way ANOVA) and non-parametric (Friedman) test of significance. Letters indicate significantly different post hoc pairwise comparisons (Tukey-Kramer, P < 0.05) between the months.

Variables	November	December	January	February	March	April	Significance values
Tree species fruiting	5.1 ± 1.1^{a}	4.1 ± 1^{ab}	2.4 ± 1.4^{d}	3.1 ± 1.4^{bcd}	3.9 ± 1.9^{abc}	4.8 ± 1.6^{a}	$F_{5,59}$ = 17.8; P < 0.001
Trees fruiting	12.8 ± 5.3^{a}	9.4 ± 5.3^{ab}	8.2 ± 4^{b}	9.2 ± 4.4^{b}	9 ± 6.5^{b}	11.5 ± 5.1^{a}	$F_{5,59}$ = 3.4; P = 0.011
Fruit abundance index	3.7 ± 1.8^{bc}	2.1 ± 0.8^{cd}	1.9 ± 0.8^{cd}	3.3 ± 1.5^{bc}	4.7 ± 1.8^{ab}	6.1 ± 2.4^{a}	Friedman X^2_5 = 38.7, P < 0.001

Relationship of food resource availability with *Trogon citreolus* abundance

In general, the months in which *T. citreolus* was abundant were those corresponding to the highest fruit availability (Fig. 2). The total fruit abundance index recorded in phenology transects and the number of trogons per point count in each month exhibited a significant correlation (r = 0.61; P < 0.001). Similarly, a significant correlation was observed between the availability of tree fruit diet only and the abundance of *T. citreolus* (r = 0.68; P < 0.001). From January to April, *T. citreolus* showed an increase in abundance and fed most frequently on *Comocladia engleriana* (19.3% in February–March), *Ficus cotinifolia* (27.3% in January), *Passiflora* sp. (6.8% in November–January), *Randia gentlei* (15.9% in December–January), and *Ampelocissus acapulcensis* (6.8% in March-April).

Discussion

Abundance and diet of *Trogon citreolus*

This study presents the first report on the abundance of *T. citreolus* in a regenerating tropical dry forest in the Mexican Pacific. The abundance of *T. citreolus* exhibited notable variation throughout the study period, with a marked increase observed in March and April, which corresponds to the end of the dry season. The observed variation in *T. citreolus* abundance may be associated with fluctuations in the availability of food resources in the study area, as demonstrated in previous studies on the quetzal (Solórzano et al. 2000) and other frugivorous birds (Levey 1988; Blendinger et al. 2012).

The Citreoline Trogon consumed the fruits of 14 plant species, mostly of *Ficus cotinifolia*, *Comocladia engleriana* and *Randia gentlei*, possibly due to their high nutritional value (Stiles 1993). *Ficus cotinifolia*, *C. engleriana*, *Spondias purpurea*, and *Forchhammeria pallida* have been reported as part of this species´ diet in conserved areas of tropical dry forest off the coast of Jalisco (Eguiarte and Martínez del Rio 1985; Morán-Dimayuga 2002). In particular, *F. cotinifolia* and *C. engleriana* are the species with the highest percentage of consumption by *T. citreolus* during the dry season on the coast of Jalisco (Morán-Dimayuga 2002), congruent with our finding in tropical regenerating dry forest. On the other hand, 10 plant species have not been previously reported (Table 1), of which *R. gentlei*, *Passiflora* sp., and *Ampelocissus acapulcensis* contribute > 5% to the Citreoline Trogon´s diet. Nonetheless, *T. citreolus* has the potential to consume these resources owing to the distinct fructification patterns of each plant species within the tropical dry forest of JBPE. *Randia gentlei* fructifies

from November to April, while *F. cotinifolia* only fructifies in January and *C. engleriana* in February and April (Fig. 3). Of these tree species, *F. cotinifolia* trees are very scarce in the study area, and their fructification period is short (about a month). However, we observed the largest number of individuals feeding on figs of this tree, in groups of up to seven individuals. In the preserved dry forests of the central Mexican Pacific, the Citreoline Trogon is observed to consume fleshy, soft, and sweet fruits that are brown, red, and red-brown in color. These fruits consist of drupes, achenes, and syconia, which are consumed whole, with the exception of larger specimens (*Pithecellobium dulce*, *Forchhammeria pallida*, *Spondias purpurea*), which are solely consumed as the pericarp (Morán-Dimayuga 2002). It is plausible that the characteristics of fruits, in addition to their availability, may exert an impact on the foraging behavior of the Citreoline Trogon. This topic is worthy of further investigation in future studies. On the other hand, the Citreoline trogon's trophic niche breadth and dietary diversity are indicative of food resources availability and fruiting patterns. These results suggest the Citreoline Trogon follows plant phenology over time and exhibits plasticity in the use of food resources. The capacity to exploit a more diverse range of resources appears to be a central factor in understanding the role of food availability on *T. citreolus* dynamics in tropical regenerating dry forest.

Our findings from the Citreoline Trogon foraging behavior study correspond with those previously reported by Eguiarte and Martínez del Rio (1985) and Morán-Dimayuga (2002), at least during the study period (dry-season), *T. citreolus* was almost exclusively frugivorous. However, Eguiarte and Martínez del Rio (1985) report two observations regarding insect consumption. We did not observe *T. citreolus* consuming insects, as has been reported for the species from July to September (wet-season) (Morán-Dimayuga 2002), and for other trogon species (Pizo 2007). This may be attributed to a reduction in insect abundance and an increased availability of fruits during the dry season in tropical dry forests (Wolda 1978a, b; Bullock and Solis-Magallanes 1990), a pattern that could occur in our study area. Other species in the genus Trogon consume insects seasonally, particularly during periods of fruit scarcity and during the breeding season when they are raising young (Riehl and Adelson 2008). Conversely, other Trogon species include insects in their diet throughout the year (Remsen et al. 1993). *Trogon citreolus* breeds during the wet season (June–October) (Valdivia-Hoeflich 2006). Therefore, we suggest evaluating this species´ diet during the wet season to gain a complete understanding of its foraging strategies in regenerating forests. Moreover, we propose assessing whether the Citreoline Trogon selects food resources based on their energy content.

Relationship of food resource availability with *Trogon citreolus* abundance

Although the study area is a site with 20 years of forest regeneration, the plants exhibited phenological variation, resulting in changes in food resource availability over time. Fruits were more abundant from February to April 2022. This pattern of variation in fruit availability is similar to that of natural forests. According to Leigh et al. (1982), fruiting peaks in tropical forests usually occur late in the dry season and early in the rainy season. Bullock and Solis-Magallanes (1990) reported larger numbers of fruiting trees in February

- March and July - August in a tropical dry forest in southwestern Mexico. Our results suggest that the dynamics of tree fructification in the study area play an important role in the abundance of *T. citreolus*. Specifically, the highest fructification rate and number of trogons feeding on fruits were recorded in March and April. Levey (1988) states that the abundance of frugivorous birds increases during the peaks of tree fructification. Berlanga-García (1991) suggests that the increase in the abundance of frugivorous birds is related to the peak fructification in Chamela, Jalisco, during March. These results support the hypothesis that fruit availability is related to changes in the abundance of fruit-eating birds (Levey 1988; Rey 1995; Blendinger et al. 2012). Alternatively, the relationship between trogon abundance and tree fructification suggests that trogons follow food resource availability in regenerating forests. During the study period, we observed that trogons fed on a variety of plants (Table 1) that display specific phenological patterns.

Conservation implications

At a global level, tropical forests experience high rates of deforestation due to anthropogenic activities (Laurance 1999). In America, deforestation is especially extensive and accelerated due to changes in land use, increased agriculture, and livestock (Hansen et al. 2013). When native vegetation is removed and habitat size is reduced, fruit-eating birds are the first to disappear (Sodhi et al. 2008). Botanical gardens play an important role in conserving local fruit-eating birds (Li et al. 2014).

Although the JBPE only covers 16.7 hectares and is currently undergoing a 20-year process of plant repopulation, it is a critical site for maintaining the population dynamics of *T. citreolus*. As previously mentioned, the abundance of the Citreoline Trogon is directly related to plant phenology. Therefore, the JBPE plays a crucial role in conserving not only the Citreoline Trogon but also the 95 species of resident and migratory birds recorded in the study area (Bojorges-Baños 2012). The Universidad del Mar protects the JBPE area with support from the state government. Nonetheless, the persistent degradation of the forest remnants situated around the botanical garden has resulted in isolation, thereby jeopardizing the long-term survival of birdlife. We believe it is crucial to preserve *T. citreolus* and other frugivorous birds to maintain the plant dynamics of the JBPE and the surrounding forest remnants. In the JBPE, we observed other frugivorous birds feeding on fruits, including *Ortalis poliocephala*, *Amazona finschi*, *Eupsittula canicularis*, *Piaya cayana*, *Momotus mexicanus*, *Cyanocorax formosus*, *Turdus rufopalliatus*, *Myiarchus cinerascens*, *Tyrannus vociferans*, *Piranga rubra*, *P. flava*, and *Habia rubica*. These birds play a crucial role in the early stages of plant regeneration by dispersing seeds from degraded forests (Wunderle 1997). The conservation of frugivores is essential for maintaining the genetic flow of plants and the vegetation structure in the study area (Terborgh et al. 1990; dos Santos 2006), as they are the primary seed dispersers.

The study provides fundamental information for future conservation policies and research on frugivorous birds, and highlights the significance of restoring natural vegetation in degraded forests. In this regard, the regeneration of forests plays a crucial role in preserving the interactions between plants and

frugivorous birds. The analysis of interspecific interaction networks can be used to assess the structure and function of biotic communities in regenerating forests. This approach allows for better understanding and conservation of ecological processes in such forests (Ramos-Robles et al. 2018; Wang et al. 2023). The present vegetation conditions at JBPE present an opportunity for future research on the ecological interactions between fruit-eating birds and the plants that constitute a component of their diet.

Conclusion

The abundance of *Trogon citreolus* showed temporal variation corresponding to fluctuations in the availability of food resources throughout the study period. Given the paucity of data regarding the population size of *T. citreolus*, it is imperative to maintain a program of monitoring the population of this species and its habitat associations. Population size is a crucial factor in assessing species risk and conservation status. The dietary breadth and dietary switching of the Citreoline Trogon enable the species to adapt to fluctuations in fruit availability in regenerating forests, indicating that its foraging behavior is influenced by the availability of food species and abundance. Further research is required during the wet season to obtain a comprehensive account of the Citreoline Trogon foraging strategies in the context of regenerating forests. Our findings highlight the ecological importance of forest regeneration in providing food resources for *T. citreolus* and other frugivorous birds. Concurrently, the presence of the Citreoline Trogon and other frugivorous birds facilitates the recuperation of regenerating forests by dispersing seeds during the dry season.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Esmeralda Floreán-Díaz: field work, data analysis, writing, original draft, review. Miguel Ángel De Labra-Hernández: conceptualization, field work, data analysis, writing, original draft, review, editing, approval.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

List of plants recorded in the phenology transects within the regenerating dry tropical forest of the Puerto Escondido Botanical Garden (UMAR)

Authors: Esmeralda Floreán-Díaz, Miguel Ángel De Labra-Hernández

Data type: docx

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